MEASUREMENTS OF FACIAL POINTS DURING GROWTH UTILIZING CENTROIDS

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الغرض من هذا البحث هو التحقق من الحركة الوجهية للنقاط السيفالومتريه خلال النمو في الاتجاه الرأسي والأفقي .
تم إجراء (١٨) عينة شعاعية سيفالومتريه لفترة طويلة ،تتكون العينة من (٧ إناث و ١١ ذكر)وتتراوح أعمـــارهم مـــا بـــين ٩ سنوات + شهرين و ١٦ سنة + شهرين ، العينة خططت ورسمت بواسطة الكمبيوتر.
خمسة عشر نقطة سفالوميتريه حددت لكل شخص وقيست في الاتجاه الأفقي والرأسي اعتمادا على منصف الجمجمة على زاويـــة ٤٥ درجة على منصف الوجه والجمجمة.
المقاسات التي أجريت تم لها عمليات إحصائية و وجد أن أعلى نسبة مئوية في التغير للعينة كلها هو(١١,٧٥ %) للحركة الســفلية للنقطة الفكية ، و(١١,٤٦%)للحركة السفلية للنقطة الفكية. أما بالنسبة للحركة الأفقية وجدت اكبر حركة للأمام للنقطة الممثلــة للفك العلوي وكذلك للأسنان الأمامية للفك العلوي والفك السفلي والنقطة الذقنية الممثلة للفك السفلي.
وجد أن هناك اختلاف بين الذكور والإناث للنقاط الواقعة في الحد الأمامي للفك السفلي في الاتجاه الرأسي والأفقـــي ، النقـــاط الوحيدة التي في منتصف الوجه التي فيها اختلاف في الاتجاه الأفقي هي النقطة الممثلة للفك العلوي والأسنان الأمامية و السفلية.

The aim of the present study was to investigate the movement of facial cephalometric points during growth in a vertical and horizontal direction. A sample of 36 lateral skull radiographs were selected from a bigger sample. Half of the radiographs were taken at aged 9 years ± 2 months and the other 18 radiographs were taken at 16 years ± 2 months. The sample was traced and digitized. The computer was able to produce a line joining the centres of the skull, cranium and face CFC (Cranio Facial Centroid line). Fifteen (15) cephalometric points were located for each subject and measured to a horizontal and a vertical line, based on the centre of the cranium and oriented 45° to the CFC. Millimetric measurements were used to calculate ratios. The data were subjected to descriptive statistics and student t-test. The greatest percentage change for the pooled sample was 11.75% upward movement for Nasion (SD± 17.90) and 11.46% downward movement for Gonion (SD ± 3.25). Horizontally, the greatest forward movement was for point A, maxillary and mandibular central incisors, point B, pogonion, Menton, Gnathion and Gonion. There was significant difference between girls and boys in the vertical direction for point B, pogonion, Gnathion and Menton. While in the horizontal direction, significant differences were found for ANS, point A, Apex and tip upper and lower incisor, point B, pogonion, Gnathion, Menton and Condylion.

Introduction

Interest in methods for predicting facial growth has contributed a great deal to orthodontic diagnosis and treatment planning during the last few decades.

One early attempt was that of Broadbent[1] who used a longitudinal cephalometric survey to assess the downward and forward path of facial growth. He concluded that the facial pattern became established at the completion of the deciduous dentition.

Brodie[23] used Broadbent's material to investigate growth at various points in the skull. He concluded that the morphogenetic pattern of a human individual is established at three months and that once attained, it does not change. He stated "the whole face is stable and that the only area of adjustment available is to be found in the teeth and alveolar process."[4]

Meanwhile, other studies have shown that the "pattern stability" concept does not apply to all individual cases. Goldstein[5] showed that the height of the face grew most and at the highest rate, then its depth and finally its width.

Bjork[6] studied facial prognathism and found that it increases during growth, which may be

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due to the alteration in relationship between the cranial base and jaw length. There was a slightly greater increase in mandibular prognathism as compared with maxillary prognathism. This was further associated with the increase in ramus height. Later, this study was confirmed by Lande.[7]

Brodie[8] discussed facial growth and found that the nasal floor tends to remain stable. In contrast, the portion was found to vary in both horizontal and vertical directions.

In an extensive study, Enlow[9,10] believed that the continued growth of the facial skeleton involved "all parts in each individual bone undergoing an extreme, complex series of successive remodelling changes."

Kerr[11] investigated those dento-facial changes which resulted from growth on longitudinal material of 85 lateral skull cephalostats at 5, 10 and 15 years. He superimposed the film on de Coster's and the sella-nasion line. In this study, considerable individual variation was recorded.

From the above studies, it is clear that research workers superimpose cephalograms (or tracings) routinely to visualize growth increments although there are inherent errors in such a method. Meanwhile, Bjork[12,13,14] introduced a measure of consistency by inserting metal (vitallium) implants under local anesthesia into the facial bones of children to facilitate growth studies. He differentiated between movements or displacements of each bone and growth at the bony surface due to remodelling. This technique was also used by Robertson[15] on neonate cleft palate patients. However, its infallibility was questioned by Julius[16] who found that migration and dislodgment of the implants caused significant error in implant superimposition.

So far, two main types of facial growth predictions have been used. The first type uses statistical information on average growth increments according to the age and the sex of the subject.[17,18] Because of the properties of statistical rules, such predictions will be reasonably correct in a majority of cases, but unfortunately they are less likely to be correct in subjects whose facial growth deviates markedly from the norm and where prediction, from a clinical point of view, is most needed.

The second type uses selected features of the facial structure of the patient to predict future development trends. Among such methods are the presence or absence of a series of structural traits in the lower face,-[19,20] the classification of facial structure into facial types, each with their own growth potential.[21,22]

Solow and Nielsen[23] found a relationship between cranio cervical posture in pre-pubertal children and the direction of facial development during the subsequent period of growth.

Johnson[24] criticized the conventional tracings which used anatomical points as references and for measuring changes during growth and orthodontic treatment. He introduced points and baselines related to centres of area (centroids) within the projected skull outline. He later asserted that by an accumulation of logical, circumstantial and statistical evidence, the centre of area of the tracing of a lateral skull cephalogram appeared to be its least variable point, while the least variable line was that connecting the centres of the cranium, skull and face.[25]

From the review of literature, it seems that methods employed to study the nature of facial growth are numerous and lack consistency and popularity. The reason may be that there is no stable reference line or plane to relate moving skeletal structures to it. Alternatively, a mathematical solution may be of significance to accurately assess facial growth. Therefore, measurements of movements for facial cephalometric points in this study will be assessed using the centroid based analysis.

Materials and Methods

Materials

Thirty-six lateral skull radiographs of eighteen subjects were used in this study, 11 boys and 7 girls. Half of the radiographs were taken at the age of 9 years and the other 18 radiographs were taken at the age of 16 years. The radiographs were selected so that they depict the presence of a complete outer cranium outline for centroid measurements. The radiographs were selected from a bigger sample collected by Professor B.C. Leighton of the King's College Dental Hospital, England.

Methods

i) The lateral radiographs were traced in a routine manner and cephalometric points were located.

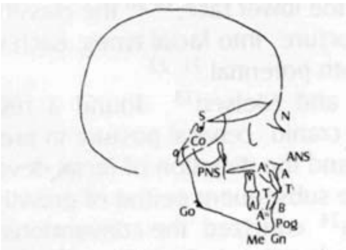

Fig. 1. Cephalometric points used.

ii) Cephalometric points (Fig. 1) used in this study were:

1. Sella	S
2. Nasion	N
3. Anterior nasal spine	ANS
4. Posterior nasal spine	PNS
5. Point A	A
6. Apex of upper central incisor	A^
7. Tip of upper central incisor	T^
8. Tip of lower central incisor	T
9. Apex of lower central incisor	A*
1 Point B	B
1 Pogonion	POg
1 Gnathion	Gn
1 . Menton	Me
1 . Gonion	Go
1 . Condylion	Co

iii) Centroid measurements: After the lateral radiographs were traced, the sample was digitized using an Apple ME enhanced personal computer to locate the centroids. The craniofacial centroid line (CFC) was located by joining the centres of cranium and face to the centre of the skull. (Fig. 2)

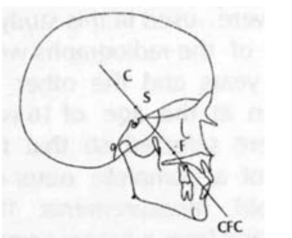

Fig. 2. Craniofacial centroid line (CFC) where C - centre of cranium, S - centre of skull, F - centre of face.

iv) Locating the vertical and horizontal lines for measurements:

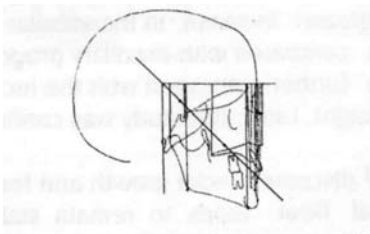

Fig. 3. Vertical measurements used.

From the centre of cranium "C" and along the craniofacial centroid a line at 45° degree angle was drawn clockwise and vertically (Fig. 3) and at 45° degree anti-clockwise line was drawn horizontally (Fig. 4).

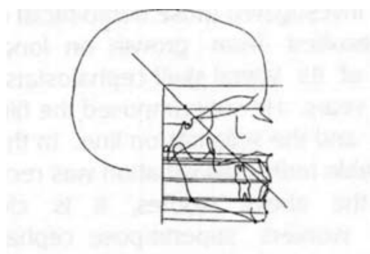

Fig. 4. Horizontal measurements used.

Cephalometric points were measured linearly to the nearest half-millimeter from the vertical and the horizontal lines by dropping perpendiculars to them. To eliminate linear distortions between subjects, ratios between points were calculated.

Statistical Analysis

The data were subjected to descriptive statistics and student t-test. Ratios of movements in horizontal and vertical directions were calculated as the ratio of parameter 1 (P,) where:

$$P_1 = \frac{\text{Linear measurement at 16 years} - \text{linear measurement at 9 years}}{\text{Linear measurement at 9 years}} \times 100$$

Results

In the vertical dimension, all points measured showed a consistently downward shift except for points Sella and Nasion which moved upwards with Nasion moving more upwards than Sella. The standard deviation for points Nasion, apices of upper incisor and lower incisor were the highest among other measured points.

Table 1. Descriptive statistics for horizontal measurements in mm (boys and girls at 9 years and 16 years).

	Age	n	Mean	S.D.	S.E.	Min.	Max.	Range
Sella*	**9**	18	36.75	0.25	0.06	31.5	41	9.5
	16	18	37.61	0.23	0.05	32	42	10
Nasion	**9**	18	105	0.44	0.11	98	118	20
	16	18	110.13	0.45	0.10	99.5	119	19.5
ANS	**9**	18	109.11	0.40	0.09	101.1	117	15.9
	16	18	117.16	0.97	0.23	104	129	25
PNS	**9**	18	61.69	0.28	0.06	55	66	11
	16	18	63.66	0.33	0.08	28	69	41
A	**9**	18	104.36	0.29	0.07	98	109	11
	16	18	113.44	0.49	0.12	104	129	25
Apex A	**9**	18	99.88	0.41	0.10	93	108	15
	16	18	108.94	0.45	0.12	99	117	18
Tip T	**9**	18	109.38	0.46	0.11	102	123	21
	16	18	119.77	0.56	0.13	112	136	24
TipT	**9**	18	104.61	0.40	0.09	98	112	14
	16	18	115.94	0.45	0.11	108	123	15
Apex A	**9**	18	94.83	0.44	0.10	89	103	14
	16	18	105.77	0.45	0.11	98	110	12
B	**9**	18	100.77	0.38	0.09	96	108	12
	16	18	112.66	0.43	0.10	105	119	14
Pog	**9**	18	102.6	0.49	0.12	96	111	15
	16	18	115.83	0.57	0.13	107	126	19
Gn	**9**	18	99.22	0.53	0.12	92	110	18
	16	18	113.27	0.63	0.15	101	125	24
Me	**9**	18	92.72	0.54	0.13	83	101	18
	16	18	106.44	0.62	0.15	97	118	21
Go	**9**	18	35.27	0.43	0.10	29	45	16
	16	18	38.41	0.26	0.06	34	44	10
Co	**9**	18	21.77	0.32	0.08	16	27	11
	16	18	22.11	0.32	0.08	16	27	11

* Please see Figure 1.

In the horizontal dimension, all points moved forwards at different rates. Points Gonion, Menton and Condylion had the greatest standard deviations, respectively, (Tables 1, 2 and 3).

Table 2. Descriptive statistics for measurements in mm in the vertical plane (boys and girls).

	Age	n	Mean	S.D.	S.E.	Min.	Max.	Range
Sella*	**9**	18	36.88	0.20	0.05	33	40	7
	16	18	36.08	0.22	0.05	32	39	7
Nasion	**9**	18	24.47	0.27	0.06	18	29	11
	16	18	21.55	0.47	0.11	12	29	17
ANS	**9**	18	72.44	0.26	0.06	78	1	10
	16	18	74.27	0.48	0.11	87	2.2	22
PNS	**9**	18	77.38	0.27	0.06	71	83	12
	16	18	81.38	0.32	0.08	74	87	13
A	**9**	18	76.94	0.28	0.07	72	82	10
	16	18	78.77	0.46	0.11	70	89	19
Apex A	**9**	18	78.66	0.64	0.15	72	101	29
	16	18	80	0.45	0.11	71	88	17
Tip T	**9**	18	101.16	0.36	0.08	94	108	14
	16	18	105.88	0.44	0.10	96	113	17
TipT	**9**	18	97.66	0.35	0.08	91	105	14
	16	18	102.72	0.45	0.11	94	111	17
Apex A»	**9**	18	118.72	0.67	0.16	96	128	32
	16	18	127.38	0.49	0.12	119	136	17
B	**9**	18	115.94	0.44	0.10	106	124	18
	16	18	123.16	0.49	0.12	116	133	17
Pog	**9**	18	126.50	0.40	0.09	117	134	17
	16	18	136.94	0.57	0.13	127	146	19
Gn	**9**	18	132.94	0.42	0.10	124	140	16
	16	18	143.77	0.53	0.12	133	154	21
Me	**9**	18	132.33	0.36	0.08	125	139	14
	16	**18**	143.38	0.53	0.12	131	150	19
Go	**9**	18	105.83	0.49	0.12	96	118	22
	16	**18**	118	0.73	0.17	109	135	26
Co	**9**	18	63.22	0.12	0.03	55	69	14
	16	18	64.88	0.10	0.02	56	73	17

* Please see Figure 1.

Table 3. Percentage change for vertical and horizontal dimensions of cephalometric points at 9 and 16 years (Boys and Girls).

	Vertical					Horizontal				
	n	**Mean**	S.D.	**Min.**	**Max.**	**N**	**Mean**	S.D.	**Min**	**Max**
Sella*	18	-2.08	5.11	-31.15	6.06	18	2.44	3.88	-5	10.5
Nasion	18	-11.75	17.90	-45.45	22.22	18	4.94	3.44	-3.38	11.65
ANS	18	2.52	5.49	-5.12	16	18	7.37	3.14	2.97	12.6
PNS	18	5.19	3.09	0	10.52	18	3.30	5.49	-4.54	15
A	18	2.40	5.13	-6.09	12.65	18	8.70	3.67	3.77	19.23
Apex A	18	2.11	7.74	-17.82	17.33	18	9.10	3.14	2.85	15
TipT	18	4.73	4.58	-1.03	14.14	18	9.53	3.64	3.50	14.81
TipT	18	5.22	4.35	-1.05	12.76	18	10.91	4.33	4.46	18.44
Apex A»	18	7.688	.49	0	38.54	18	11.67	5.30	1.98	20.43
B	18	6.28	3.68	0	11.11	18	11.89	4.76	2.77	20.22
Pog	18	8.27	3.64	2.4	13.6	18	12.99	5.22	2.72	20.19
Me	18	8.19	3.71	2.87	13.6	18	14.26	5.21	2.77	21.27
Gn	18	8.37	3.59	1.55	13.7	18	15.01	7.19	0.99	26.67
Go	18	11.46	3.25	5.76	17.2	18	9.81	9.84	-6.97	25.80
Co	18	2.65	3.87	-6.45	10.16	18	1.78	7.4	11.11	12.5

* Please see Figure 1.

All significant differences were only found for points on the anterior border of the mandible (B point, Pogonion, Gnathion and Menton) (Table 4).

Table 4. Descriptive statistics for mean percentage change between girls and boys in vertical measurements and level of significance (P).

	Girls			Boys			
	Mean % Change			Mean % Change			
	n	**Vertical**	**S.D.**	**N**	**Vertical**	S.D.	P
Sella	7	0.67	4.35		-3.83	4.93	N.S.
Nasion	7	3.82	15.84		-16.80	17.95	N.S
ANS	7	0.23	4.47		3.98	5.76	N.S.
PNS	7	3.57	1.78		6.22	3.37,	N.S.
A	7	0.24	4.59		3.77	5.18	N.S.
Apex A	7	3.32	8.13		1.33	7.79	N.S.
TipT	7	3.28	4.57		5.66	4.55	N.S.
TipT	7	2.90	3.73		6.70	4.20	N.S.
Apex A*	7	3.76	3.30		10.16	9.92	N.S.
B	7	3.65	3.05		7.95	3.10	•
Pog	7	5.27	2.35		10.18	2.98	• •
Gn	7	4.92	2.31		10.26	2.82	...
Me	7	5.03	2.25		10.50	6.1	»
Go	7	9.87	3.33		12.46	2.90	N.S.
Co	7	0.70	4.35		3.89	3.13	N.S.

˙P < 0.05 ¨ P < 0.01 ¨ P < 0.001

All horizontal changes showed significant differences except for points: Sella, Nasion, Posterior nasal spine and Gonion (Table 5).

Table 5. Descriptive statistics for mean percentage change between girls and boys in horizontal measurements and level of significance (P).

	Girls			Boys			
	Mean % Change			Mean % Change			
	n	**Horizontal**	S.D.	**n**	**Horizontal**	S.D.	P
Sella	7	0.80	4.17		3.49	3.48	N.S.
Nasion	7	3.08	1.69		6.13	3.80	N.S.
ANS	7	4.44	0.72		9.24	2.57	...
PNS	7	2.38	4.27		3.88	6.27	**N.S.**
A	7	6.14	1.63		10.33	3.72	*
Apex A	7	6.68	2.17		10.64	2.69	• •
TipT	7	6.88	3.19		11.21	2.91	*•
TipT	7	7.54	3.34		13.05	3.50	• •
Apex A«	7	8.11	4.35		13.94	4.69	•
B	7	8.15	4		14.26	3.60	•*
Pog	7	9.64	4.83		15.12	4.43	*
Gn	7	10.15	4.50		16.87	3.85	"
Me	7	9.02	6.07		18.82	4.98	• «
Go	7	9.25	10.91		10.17	9.64	**N.S.**
Co	7	-2.80	6.16		4.70	6.85	•

˙ P < 0.05 ¨ P < 0.01 ¨ P < 0.001

Discussion

Prediction of facial growth studies has improved with the introduction of computerized cephalometry. The controversy in research findings in this field has led workers to employ several methods to study facial growth. Tine problem seems to be that points tend to grow away from each other in three planes as there is no fixed point to use as a stable reference. Using the centroid method in this study as proposed by Johnson[23-24] seems to be logical since the center of an irregular shape is the most stable reference while other points are in motion. Also, using the centroid of the cranium as a reference enables this study to reduce differences of shapes as much as possible since the general outline of the cranium is established at an early age (Fig. 5).

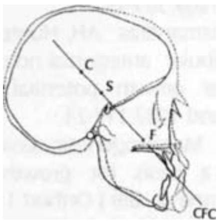

Fig. 5. Male tracing at 9 years (solid line) superimposed on one at 16 years (dotted line) Cranio Facial Centroid line (CFC).

From the outset, the results of this longitudinal study clearly showed that cephalometric points moved horizontally and vertically in a forward and downward direction except for Sella and Nasion which moved upwards confirming other studies.[10]

When percentage changes were calculated between points at age 9 and 16 years, it was observed that Nasion, Pogonion, Gnathion, Menton and Gonion had the highest change with Nasion having the greatest S.D. ± 17.90. This finding indicates that changes at Nasion point does not qualify Nasion to be used as a stable reference. On the horizontal plane, it was observed that all points moved forwards with some having greater variability as Menton, Gonion and Condylion.

When the sample was broken down to males and females in the vertical dimension, only points on the anterior and inferior contour of the chin were significantly different with males showing greater vertical growth than females while there was no differences between both groups in the upper and middle face region (Table 4).

However, when both samples were tested in the horizontal dimension, significant changes were found for skeletal and dental points (Table 5). Tables 4 and 5 show an interesting pattern of growth in vertical and horizontal directions. Anterior nasal spine did not show a difference in growth between both groups in the vertical direction but did differ significantly in the horizontal direction with males showing more forward growth than females. Point A showed a similar pattern of growth. The apices and tips of maxillary and mandibular incisors followed point A and ANS. There was also a significant difference between males and females in the vertical and the horizontal growth directions for points B, Pogonion, Gnathion and Menton. However, point Condylion was not significantly different in the vertical direction but was significantly different in the horizontal direction. This is attributed to its backward growth in girls as compared to boys. However, it moved downwards for boys and girls equally. This may be explained by the fact that the boys grow significantly more anteriorly than girls followed by a compensatory forward movement of the mandible.

In this study, it would be more useful had a greater number of subjects were used, particularly in the females. However, utilizing the centroid-based analysis employed the inclusion of the skull periphery which was not present in all x-ray tracings.

This initial study to investigate directional movements of facial bones suggested that the centroid analysis could be a suitable candidate for reference purposes.

Utilizing centroid based analysis, a larger sample in future studies ought to be used in order to understand more about the nature of facial growth and hence be able to predict it accurately.

Conclusion

A new mathematical method was introduced in this study to estimate craniofacial growth changes in anatomic points.

Vertical and horizontal growth changes were calculated in millimeters and percentages for a sample of eleven boys and seven girls at ages 9 and 16 years.

The greatest percentage change for the pooled sample was 11.75% upward movement for Nasion

(S.D ±17.90) and 11.46% downward movement for Gonion(S.D. ±3.25).

Significant differences between girls and boys in the vertical direction were observed for point B, Pogonion, Gnathion and Mention. While in the horizontal direction, significant differences were found for ANS, point A, Apex and tip of upper incisor and tip of upper incisor and tip of lower incisor, point B, Pogonion, Gnathion, Menton and Condylion.

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